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RESEARCH AND APPLICATION[1]

FOR nearly half a century, it has been the custom in this society to give its president every year "his day in court," and in conformity therewith many brilliant addresses have been delivered, and almost every conceivable subject has been discussed. It is therefore becoming more and more difficult for the incumbent to select a theme which shall have the merit of novelty, unless, perchance, he is himself working in the laboratory, and can bring forth some new and shining example of the progress of his science. I have not the good fortune to be so situated, and I must perforce satisfy myself with some other line of procedure in the hope that even in a discussion of old and well-known facts, some new light may be thrown, which will not be altogether without value. I have therefore selected for my subject, "Research and Application," knowing that many of my hearers have been spending their lives in considering and teaching it, and are far better prepared to instruct me than I am to reciprocate. I would remind such that there is at last a large and growing number of people who are intensely interested in what the chemist has done and is doing and still more in what he will accomplish in the future. It is therefore rather to that public, many representatives of which are present to-night, than to the chemists in this gathering that I would address myself.

Research in the distant past was the privilege of the few. In chemistry, during the middle ages, the alchemists were practically the only ones pursuing it, and they in secret, and not always from the highest of motives. Working by themselves, as they did, they had not the great advantage of meeting and discussing with others similarly engaged, and using their progress and mistakes to intensify

[1] Address of the president of the American Chemical Society, Philadelphia, September 4, 1919.

their own increase in knowledge. Thus it has come about that the science of chemistry is little more than a century old, and its tremendous advances only a few decades. The first chemical society in the world was born in Philadelphia in 1793, and yet the real advances have been made since the formation of this society in 1876. Since that time, however, the advance in knowledge has been startling, not alone in this country, of course, but in all civilized countries. It is not boasting to say, however, that during all that time, the progress in this country has been in no wise behind that of the best anywhere, which our public is at last beginning to recognize. Particularly during the trying period of the war, when vast and new problems were suddenly thrust upon them, the work of our chemists has been beyond praise.

At the foundation of all this advance, research is firmly imbedded. Without it, the structure could not have risen, or the glowing anticipations of the future even imagined. Twenty centuries ago, we were told "Seek and ye shall find; knock and it shall be opened unto you." No one can deny that there have been accidental discoveries, some of great moment; but this has not been and will not be a safe dependence. Walking on the street one day, I picked up a roll of bills, whose owner curiously enough could not be found; but this did not lead me to give up my ordinary occupations, and wander around the streets of New York with the hope of further and continued good fortune of like character. Accidental discoveries are not to be relied on, of course, although they are not to be scorned. In chemistry the accidental good fortunes have usually come to those who were really seeking, although possibly for something far different, but, note this, they were usually made by men qualified to recognize an important discovery when it flashed across their vision.

Research, of course, is not of necessity to result in invention. It may in that respect terminate in a cul-de-sac from which with present knowledge there is no egress, or what more frequently happens, it may lead to a line of reasoning, which in time leads to another, and so on, until suddenly a bright light illumines the way, and a goal of the greatest possible importance is attained. Many instances illustrative of this will occur to you. I will cite only one, and that one because of the importance it has assumed in the light of recent developments.

As early as 1882 scientists rigidly established by chemical research what chemists call the "constitution" of the blue vegetable dye, indigo, and clinched that scientific conclusion by preparing the identical material in the laboratory. This particular important addition to human knowledge has remained a discovery merely; yet it so stimulated the search for practicable methods of applying that discovery to human needs that voluminous researches in a number of European countries were undertaken almost at once for that purpose. Of the host of scientific discoveries made as the direct result of chemical research in this direction, one was selected in 1897 as of such promise as to warrant the expectation that it would successfully displace vegetable indigo. Such was the ultimate fact. But, in 1901, others succeeded in devising a commercial mode of making indigo which was so formidable a rival to the mode adopted in 1897 that it seriously and at once threatened the supremacy of the latter, a thing which is now, some eighteen years later, actually coming to pass. It is worth while reflecting that the men who accomplished the scientific work of 1882 themselves never succeeded in making that work anything more than a discovery, despite the fact that for more than fifteen years they energetically tried to do so, and in their efforts they had the close cooperation of a large commercial organization. However, it remained for a college professor of chemistry in another country and himself working in quite a different field, and as a direct result of that work, to hit upon the central idea of the successful indigo mode of 1897 and to clinch it by appropriate laboratory methods. Yet his work remained for almost seven years a discovery only—a promising discovery to be sure—until the intensive work of others, overcoming many obstacles, made it serviceable to mankind. These two sets of workers were engaged in the same general class of chemical research, that

is, they were working in the organic division of chemistry. As you know, chemistry is serviceably, even though crudely, grouped under two grand divisions, organic and inorganic, and for many years these were treated quite separately from each other; I know "organic" chemists who look with mild indulgence upon the "inorganic" chemists and I also know inorganic chemists who return the compliment —with interest. In 1901, however, one of these so-called "inorganic" chemists, in searching for new worlds to conquer, hit upon an idea which he thought would make one of the discarded and discredited methods of making indigo a worthy rival of the only commercially successful indigo method of that day. And he was right! The owners of the 1897 method were forced to look to their laurels.

The history of the synthetic production of indigo is filled with many different discoveries of how indigo may be made in the laboratory, most of them wholly unrelated to the methods of 1882, 1897 and 1901. Two, at least, of them have made an unsuccessful and short-lived attempt to grow into an invention capable of meeting competitive conditions. Now, it is curious to note that the 1901 method was an offspring of the cyanide method of extracting gold which in turn is the gold-extraction method that made the South African gold fields so valuable. Immense amounts of that deadly poison, sodium cyanide, were needed in preparation for this gold extraction; that, in turn, called for unusually large amounts of other things and among these was that particular inorganic material that gave competitive ability in the world's markets to one of the theretofore discarded indigo methods. From the gold fields of South Africa to synthetic indigo is, indeed, a long cry. Is it, therefore, not wholly reasonable to expect that from some other equally far-off branch of chemical industry or of chemical research may come the proper stimulus to bring to active competitive life some of these other discarded indigo methods or even to create new methods superior to any we know of to-day? Among chemists we also distinguish physical chemists who are curious about subjects in that great twilight zone between the field of chemistry on the one hand and of physics on the other; also we have the electrochemist who is always searching for more or less direct chemical applications of the electric current. Just as the inorganic chemist in 1901 taught the organic chemist the secret of endowing a discarded indigo method with competitive life, may we not reasonably expect that some day the physical chemist and the electrochemist may, one or both, in the course of wholly unrelated chemical research work, come across facts which when intelligently applied to the indigo problem may still further advance it?

The chemical knowledge and research that enter into the synthetic production of indigo, as we know it to-day, come from over three generations of chemists, scattered all over the globe, speaking many languages, researching on many different and separate problems which touch almost every phase of human endeavor, and the end is not yet.

For centuries indigo has been the undisputed king among dyes. Chemists have made many attempts to displace it by other dyes, but it has so far successfully withstood all such attacks upon it—except as to its source or origin. Indigo is still the king, but its supremacy is threatened and threatened seriously and its undoing, if that should ensue, is traceable directly to itself. Chemists have long felt sure that the true reason for the supremacy of indigo lay in the manner in which it dyes fabric. It possesses the unique faculty of being, what you have all so often read of in the daily papers, a "vat" dye. It is the pioneer vat-dye and until comparatively recently it was the only vat-dye. Vain attempts to create or imitate this vat-dyeing property in other dyes are recorded by the score in the history of coal tar dyes. But, about twenty years ago, a real vat-dye was constructed in a research laboratory which ultimately turned out to have an entirely different constitution from indigo. This supplied the key to an entirely new class of dyes. Although among the multitudes of "vat" dyes constructed along these new lines many are wholly worthless, there are, nevertheless, a

goodly number of them having all the desired advantages of indigo and others equally numerous, possessing highly prized advantages which indigo lacks. All of these good ones are free from certain disadvantages of indigo and, what is more important, their shades cover every tint in the rainbow satisfactorily except the reds and those can not much longer elude the searchers. Some day a new blue dye may result from these researches or from other researches growing out of them and indigo will no longer be king. In still other directions the chemical study of indigo has been fruitful. By proceeding along lines similar to those of the 1897 method, but displacing the nitrogen by sulfur, an entirely new line of materials has been made accessible through chemical research and no man is wise enough to place the limit upon the directions and the extent that chemical ingenuity and research will ultimately go in this one very small field of chemical effort, which requires and draws upon all the sources of chemical knowledge we have. The possibilities seem limitless.

True research must be intentional and intensive. We must really seek if we would find. We must really knock at the doors of the secret chambers of knowledge, if they are to be opened to us. We must have imagination, it is true, but we must have more than that. There must be the foundation of sound education, and the ability to extend it to embrace new and unexpected knowledge, and apply this in turn as we progress upwards.

To fit a man for research in chemistry or any other science, many things must be accomplished before the candidate is ready to take his first advanced step. Many methods of procedure have been suggested, and some heat of argument generated; but all agree that education which produces real practical knowledge is absolutely essential. All agree, also, that the person to be prepared must be a likely subject; and that energy and time should not be wasted on those who do not show that they possess certain necessary qualifications. I think that it will also be generally admitted that the teacher himself should not only have great attainments, but must also possess the rare quality of being able to transmit knowledge in such a way that it will be truly absorbed by the pupil and form part of him. One of the greatest mathematicians I have ever known was about the poorest teacher. He knew but could not impart. The future of the world, therefore, depends in a very large degree, on the teacher in the school and on the professor in the college. They have an opportunity to mold the world, which many of them thoroughly appreciate. Alas, in most instances, the consciousness of work well done is about their only reward. Some day, and I hope not a very distant one, it will be generally recognized that, like other laborers, they are worthy of their hire, and their compensation will more nearly approximate the value of the work done. When that happy day arrives, they may experience a little less of the satisfaction of sacrifice, but they will have other comforts and hopes which will more than make this up to them and to their families. Like others before me, I advise the people of this country that they can make no better investment than one liberal enough to cause the teaching profession to attract not only those whose high sense of duty leads them to embrace it at a sacrifice, but also those who can not afford to make the sacrifice, however anxious they may be to do so. Men preparing for research must have the best men in the country to guide them, and it is not fair to expect these men, as so many have done in the past, to live the narrowing life of poverty. Neither is it wise.

There are a few foundations specifically provided for chemical research, such as the Warren Fund of the American Academy of Arts and Sciences, the C. M. Warren Fund of Harvard University, and the Wolcott Gibbs Fund of the National Academy of Sciences. There are a number of foundations for promoting research generally which have included chemical research within their fields, such as the Bache Fund of the National Academy of Sciences and the Elizabeth Thompson Science Fund. The Rockefeller Institute for Medical Research fosters chemical research contributory to its main object, the Carnegie Institution of Washington supports

chemical research in its general policy of advancing knowledge through research. The newest of all is the fund recently placed at the disposal of the National Research Council for stimulating chemical research. There is need for many more foundations if we are to keep pace with the rapid strides of civilization, or better still, to determine the direction they will take.

The importance of research is being more and more recognized and understood by the public. One of the most encouraging evidences of this is shown in the preamble and resolution adopted recently by the American Federation of Labor at Atlantic City, indicating, as these do, a clear appreciation by that great association of how much we all depend on what science will disclose to ameliorate the conditions of the future. It is well worth while to read these in full here. They are as follows:

WHEREAS, scientific research and the technical application of results of research form a fundamental basis upon which the development of our industries, manufacturing, agriculture, mining and others must rest; and

WHEREAS, the productivity of industry is greatly increased by the technical application of the results of scientific research in physics, chemistry, biology and geology, in engineering and agriculture, and in the related sciences; and the health and well-being not only of the workers but of the whole population as well, are dependent upon advances in medicine and sanitation; so that the value of scientific advancement to the welfare of the nation is many times greater than the cost of the necessary research; and

WHEREAS, the increased productivity of industry resulting from scientific research is a most potent factor in the ever-increasing struggle of the workers to raise their standards of living, and the importance of this factor must steadily increase since there is a limit beyond which the average standard of living of the whole population can not progress by the usual methods of readjustment, which limit can only be raised by research and the utilization of the results of research in industry; and

WHEREAS, there are numerous important and pressing problems of administration and regulation now faced by federal, state and local governments, the wise solution of which depends upon scientific and technical research; and

WHEREAS, the war has brought home to all the nations engaged in the overwhelming importance of science and technology to national welfare, whether in war or in peace, and not only is private initiative attempting to organize far-reaching research in these fields on a national scale, but in several countries governmental participation and support of such undertaking are already active; therefore be it

Resolved, by the American Federation of Labor in convention assembled, that a broad program of scientific and technical research is of major importance to the national welfare and should be fostered in every way by the federal government, and that the activities of the government itself in such research should be adequately and generously supported in order that the work may be greatly strengthened and extended; and the secretary of the federation is instructed to transmit copies of this resolution to the President of the United States, to the president pro tempore of the Senate, and to the Speaker of the House of Representatives.

I hope and believe that this matter coming as it does from a new direction will be most seriously considered by the proper authorities —not that it has not already been well understood in Washington, but that renewed interest may be taken and even more liberal appropriations granted. The federation resolution urges that "a broad program of scientific and technical research is of major importance to the national welfare." Good! Now that everybody is agreed, how was it possible that for so long a time this belief was held by so few, and these composed almost entirely of men of science? The question, therefore, is squarely before the country, and the urgency of it thoroughly appreciated by those who have the most to gain by it; namely, the workers on whose efficiency so much depends. Now this opens the way to a scientific solution of vital questions about which there has been such fundamental differences of opinion, based largely on what may be called the point of view. People have divided themselves into classes—a very dangerous course—and many —a very great many—have actually believed that there must of necessity be a deeply rooted

difference between capital and labor, and that the true interests of either were entirely apart from those of the other. Many have held that labor is a commodity which it was to their best interest to get the most of for the least money, while many others believed that labor was the sole source of all wealth, and that the fewer hours worked, and the smaller the output of those hours, the better it would be, somehow or another, for the laboring classes. I have cited the extreme views for purpose of illustration, realizing the somewhere between the two would be found the great body of all reasonable and thoughtful men. We may leave out of consideration here that ultra-extreme class who teach, whether they believe it or not, that the true interests of labor would be best served by sabotage and syndicalism, and all the other fantastic notions which have of late years been more or less in evidence, and liable to catch the unwary. To these, research presents no attractions.

Now I am going to venture to suggest to the working man who is earnestly desirous of bettering his own and his family's condition, that there are a good many sciences besides chemistry and the engineering and abstract sciences in general. Some of these he is better able to study and practise than any one else. Many of the fundamental truths concerning labor and its conditions would never be discovered by the scientist per se, because he has not had the benefit of practical preparation. Let our friends of the American Federation of Labor not be content with what the government can do in the line of their resolution, good as it has been and will be, but let them start a carefully planned series of researches themselves, and follow them up until the truth stands revealed. They can depend upon the assistance of this great society. The employers of labor have been doing this for years, singly and in groups, seeking the same end. The shining goal of all research is the truth, the whole truth, and nothing but the truth. Thus, starting from different angles, with fairness and thoroughness, the various so-called interests will arrive at the same truth, for there can only be one truth concerning any question. Thus will it come to pass that capital and labor will discover that the true interest of one is the true interest of all, and instead of bickerings and suspicions we will have that cordial cooperation which is absolutely essential if we could get the best out of this good old world of ours.

Scientific discovery is really not a haphazard matter. The art of making it can be cultivated, and definite rules of research can be laid down. Many elements enter into the problem and these have been very well tabulated by the late Dr. Gore, F.R.S., in his book, "The Art of Scientific Discovery." While the list he gives may not be complete, it is so nearly so that it is well worth quoting here. His table is as follows:

1. Aid to analogy.
2. Hypotheses.
3. Analysis and synthesis.
4. Application of (*a*) electricity to bodies; (*b*) heat to substances.
5. Asking questions and testing such questions.
6. Assumptions that—
    - (*a*) There is certainty of all the great principles of science.
    - (*b*) Complete homologous series exist.
    - (*c*) Converse principles of action exist.
    - (*d*) Certain general statements which are true of one force or substance are true to some extent of others.
7. Combined action of many observers.
8. Comparison of—
    - (*a*) Facts, and collecting similar ones.
    - (*b*) Collections of facts with each other
    - (*c*) Facts with hypotheses.
    - (*c*) The orders of collections of facts.
    - (*d*) Facts with hypotheses.
9. Deducting process.
10. Employment of new or improved means of observation.
11. Examination of—
    - (*a*) Common but neglected substances.
    - (*b*) Effects of forces on substances.
    - (*c*) Effects of contact on substances.
    - (*d*) Effects of extreme degrees of force.
    - (*e*) Extreme or conspicuous instances.
    - (*f*) Influence of time upon phenomena.
    - (*g*) Neglected truths and hypotheses.
    - (*h*) Peculiar minerals.
    - (*i*) Unexpected truths.
    - (*j*) Rare substances.
    - (*k*) Residue phenomena.

(l) Residues of manufacture.
(m) The ashes of rare plants and animals.

12. Extension of—
(a) The researches of others.
(b) The researches of neglected parts of science.

13. Inductive process.

14. Investigations of—
(a) Exceptional cases.
(b) Unexplained phenomena.
(c) Classification unexplained.

15. Means of—
(a) Converse experiments.
(b) Hypotheses.
(c) Homologous series.
(d) Instruments of great power.
(e) Improved methods of intellectual operation.
(f) Measurements.
(g) The method of curves.
(h) The method of least squares.
(i) The method of means.
(j) The method of residues.
(k) New instruments.
(l) Modes of observation.
(m) Observations.
(n) More intelligent and acute observation.
(o) Additional observations by known methods.
(p) Periodic functions.
(q) More refined methods of working.
(r) Repetition of experiments.

16. Simple comparisons of facts of phenomena.

17. Search for—
(a) So-called "impossible" things.
(b) One thing and finding another.

18. Subjecting series of forces or substances to new conditions.

19. Use of—
(a) Known instruments or forces in a new way.
(b) Improved instruments.
(c) More powerful instruments.
(d) Causes by the methods of averages.
(e) Coincidences.

20. Conditions of—
(a) Scientific discovery.
(b) Determination of the nature of a discovery contrasted with barren reasoning.

21. Dependence of discovery upon art of exceptional instances.

22. Fundamental laws of discovery.

Research does not always lead to discovery, nor discovery to invention, but the sequence is logical. Gore defines the difference between discovery and invention in these words: "Discovery consists in finding new truths of nature, whilst invention consists in applying those truths to some desired purpose;" and that definition is sufficiently accurate. The natural application of research is therefore invention. How can this application and its corollaries best be carried out?

The concrete application of a truth is of course necessary for its widest usefulness. There are various theories as to the best way of accomplishing this. Take our old friend Wackford Squeers for instance—a highly interesting character in one of Dickens's best books:

> This is the first class in English spelling and philosophy, Nickleby. Now then, where's the first boy?
>
> Please, sir, he's cleaning the back parlour window, said the temporary head of the philosophical class.
>
> So he is, to be sure, rejoined Squeers. We go upon the practical mode of teaching, Nickleby; the regular educational system. C-l-e-a-n, clean; verb, active, to make bright, to scour. W-i-n, win, d-e-r, der, winder, a casement. When the boy knows this out of a book, he goes and does it. It's just the same principle as the rule of globes. Where's the second boy?
>
> Please, sir, he's weeding the garden, replied a small voice.
>
> To be sure, said Squeers, by no means disconcerted. So he is. B-o-t, bot, t-i-n, tin, bottin, n-e-y, ney, bottiney; noun, substantive; when he has learned that bottiney means a knowledge of plants, he goes and knows 'em. That's our system, Nickleby; what do you think of it?

During the intense pressure of recent years, this Squeers system has had a good trial, and seems to have left more or less to be desired. The taxpayer knows the sequel, and will be reminded of it from time to time for the rest of his life.

The application of research has always required a high order of talent. In the future, a still higher order of talent will be necessary, but in addition this talent must be prepared

by education to do this very thing. Sir Robert Hadfield, F.R.S., has said, after England had been struggling with belated preparation for nearly two years:

Until quite recently many mistakes were made, either because the scientific man had been installed in view of his special knowledge, or, at the other end of the scale, the practical man was given the preference. In a general way neither of these types has been a success.

Admitting Sir Robert's conclusion, how can we produce the leaders who shall adequately combine both qualifications? That is one of the greatest and most interesting problems awaiting solution by our educators, and on its correct solution depends in a larger degree than many imagine, the future of successful and contented industry in this country. I shall not attempt in the presence of so many educators of acknowledged ability, to show the way, even if I felt persuaded that I knew it, as the matter is of too great consequence to run the risk of an amateur indicating the wrong road. I shall content myself by pointing out the need, with the hope of turning the attention of the great public to its existence. In our free country, the people generally get what they really want, and it is worth while to lead them to want the greater things, and not to be satisfied with the lesser.

There are certain fundamentals, however, that all will agree to, if it be true that the leaders of the future will have far greater problems to solve than have yet been conceived.

1. The candidate for leadership should have a healthy body. Great things have been accomplished by men and women of fragile physique, but they would have accomplished greater if they had not been thus handicapped.

2. He should have good habits, which involves good character. This is vital if we would have leaders who would be a blessing and not a curse. We can easily call to mind men of splendid health and intellect who used these gifts to the injury of their fellows, and not to their advantage. Do not waste time or energy in educating for leadership a man of bad or doubtful character or whose aims are selfish.

3. Of course he should have a good mind, educated to the highest degree attainable. This education should be specialized in the desired direction, while good all around. No really great leader can be lop-sided if he would avoid being a "crank."

4. He should have a thorough knowledge of human nature. To play on the "harp of a thousand strings" requires on unusual acquaintance with the instrument. How many men otherwise great have broken down here, sometimes because they have given too much confidence, sometimes not enough, sometimes because they did not know how to select assistants. The knowledge of human nature is a great gift in itself, which can be acquired and increased. It lies at the foundation of wisdom, which King Solomon pronounced the "principal thing."

With the qualifications enumerated and others which will occur to you, the candidate for leadership is well equipped. To direct him to full fruition is a noble task. Let us proceed to fill our high places of every kind with the men and women specifically prepared to fill them, being assured that the effort to do so will produce an army of those not quite qualified for the top, but of the greatest value to assist those who are, and who without such aid would resemble "faith without works," we are told, is "dead being alone."

Research leads to discovery, discovery to invention, invention—no one knows where. Applied and supervised by those prepared for the task, the strides of progress will be long, and the benefit to the human race in proportion. Let us educate for living—certainly—but let us also educate for leadership—that superlative leadership of which civilization will stand more and more in need, as it increases in complexity, and reaches higher and higher planes.

Wm. H. Nichols

THE INTERALLIED CHEMICAL CONFERENCE[1]

The delegates of the Federated Chemical Societies of America, Belgium, England, France and Italy met in London, July 14 to

[1] Based on advance sheets from *Journal of Industrial and Engineering Chemistry.*